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LOSS OF HEAD IN CORPORATION COCKS AND SERVICE PIPES[1]

By Bernard J. Blejstein

Several years ago a series of tests was made by the Bureau of Investigation and Design of the Department of Water Supply, Gas and Electricity, New York City, to determine the losses of head in corporation or service cocks and service pipes. The results of these tests may prove of value to the water works profession, particularly the tests of corporation cocks, there being very little data available on that subject. All sizes in use by the department at that time were tested. Of the two largest sizes four of each type were tested and of the smaller sizes, two of each type. Of the lead and galvanized service pipes four lengths of each size about 15 feet long were tested.

The observations were very carefully made, the losses being measured by mercury deflections, and the discharges by a 2-inch meter of the current type. This type was selected rather than a meter of the disc type, as the flow through the latter caused considerably more vibration and fluctuations of the mercury deflections than a meter of the current type. The same meter was used during the entire series. It was rated on a testing machine at the beginning and end of the tests, the exact discharge at the various rates being determined by weighing.

The corporation cocks were inserted in a length of 12-inch cast iron pipe, capped and plugged at the ends, by a tapping machine in the usual manner. The main was connected to a fire hydrant through the plugged end by means of a short piece of 4-inch galvanized iron pipe. The cocks were set about a foot apart, the 2-inch cocks being set nearest the capped end of the pipe in order to eliminate any uncertainties due to swirls at the high rates of flow.

New lead pipe of a size corresponding to the size of the corporation cock and of double A weight was connected to the tail piece with the usual form of wiped joint. The meter with a control valve at the outlet end was connected to the other end of the lead pipe. The galvanized pipe was connected in a similar manner. Both the lead and the galvanized iron pipe were of the usual commercial sizes, the galvanized being of standard weight. The lengths were selected at random from a large stock. The lead pipe was handled more carefully than such pipe is usually handled in order to prevent denting or needless bending of the pipe.

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[1] Read before the St. Louis Convention, May 16, 1918.

In measuring the losses through the corporation cocks, a U-tube partly filled with mercury was used. One leg was connected by means of rubber tubing to a $\frac{1}{4}$-inch opening in the top of the main, and the other to a $\frac{1}{16}$-inch opening in the wall of the lead pipe one foot from the end of the tail piece. The rubber tubing and the upper half of the U-tube were completely filled with water. The loss measured included the velocity head, entrance head, and the frictional losses through the cock and 1 foot of lead pipe. This total loss was high, and at the high rates of flow it was necessary to connect three tubes in series, the loss being the sum of the deflections in each tube.

The losses in the pipe were measured in a similar manner, the two legs of the U-tube being connected to $\frac{1}{16}$-inch openings, 2 and 4 feet apart. Tee connections were provided at the different openings and it was thus possible to measure the losses in the corporation cock and the various sections of each length simultaneously. The sum of the losses in the various sections was used in computing the unit loss for each length.

Some difficulty was experienced at first in preventing the formation of a burr on the inside surface of the lead pipe in drilling the holes through which the pressures were transmitted. This was finally overcome by punching the holes through the walls from the inside in the following manner: Two $\frac{1}{8}$-inch holes were drilled partly through the walls of the pipe on points diametrically opposite, and one of them continued as a $\frac{1}{16}$-inch through the wall. By inserting a piece of solid drill rod through this opening, the opposite wall was punched through, leaving the inside surface quite smooth. The burr around the inside of the drilled hole was removed as much as possible with a special tool, and the hole plugged up and soldered. After the tests were completed, the pipe was cut open at each of the holes and the inside surface examined. In only two cases was a burr found and in both it was very slight.

A single $\frac{1}{16}$-inch hole was drilled through the wall of the galvanized iron pipe at each pressure point, using a high speed drill. A small burr was formed but no attempt was made to remove it, it being felt that this burr would not affect the results materially as the inside surface was already quite rough.

In taking the readings three observers were used, one to read the meter, the others to note the U-tube deflections. At each rate of flow a sufficient quantity of water was allowed to pass so that the dial hand on the meter made a complete revolution. In this way any errors due to eccentricities of the dial hand or inaccuracies in the graduations were eliminated. The time was taken with an ordinary watch, readings being taken to the nearest half second. As the total time for any individual test was never less than two minutes, the resulting error was probably less than 1 per cent. A stop watch was tried but failed to give satisfactory results as it did not always start on being released. The deflections were read at 15 second intervals, the readings being taken to the nearest $\frac{1}{16}$ inch. As no deflection was less than 1 inch and at least eight readings for each rate were taken, the resulting error is probably also well within 1 per cent. The mercury in the tubes fluctuated slightly, due to changes of pressure in the main, but these fluctuations were never more than 2 per cent of the total.

After a sufficient number of tests had been made on each length, the unit losses at the observed rates of flow were computed, 1 inch of mercury deflection being equivalent to 1.047 feet of water. These values were substituted in the Williams & Hazen formula,

$$v = c\, r^{0.63}\, s^{0.54}\, 0.001^{-0.04}$$

and the average value of c for each length obtained. From these the average value of c for each size was computed. The values of c for the same section of pipe at different rates of flow showed very little variation, the extreme varying not more than 3 per cent from the average. For different sections of the same length of pipe, however, the variation was considerable, even in the case of the lead pipe. Table 1 shows the average value of c obtained from these tests, the range in the value of c for different sections of the different lengths, and the range in the average value for the different lengths.

The diameters given are those ordinarily used in connection with lead and galvanized iron pipe, and are not the measured diameters of the actual lengths tested. Unfortunately the actual diameters are not available. The greatest variation would be expected in the galvanized pipe. Subsequently four lengths of each size of the galvanized pipe were measured by filling with water and the average diameter computed, with the result shown in table 2.

TABLE 1

Results of tests on lead and galvanized iron pipe

SIZE	DIAMETER	RANGE OF DISCHARGE	RANGE IN VALUE OF *C*		MEAN *C*
			2 ft.-4 ft. lengths	15 ft. lengths	
			Lead pipe		
inches	*inches*	*gallons per minute*			
½	0.50	2-16	130-155	144-150	148
⅝	0.625	2-22	140-165	147-157	152
¾	0.75	5-50	120-148	124-143	137
1	1.00	10-80	121-140	131-138	134
1½	1.50	20-200	120-149	138-143	139
2	2.00	60-300	140-170	157-162	160
			Galvanized iron pipe		
½	0.623	2-18	78-110	92-97	94
¾	0.824	5-50	88-125	97-104	101
1	1.048	10-80	100-125	106-110	109
1½	1.611	20-200	95-115	101-105	103
2	2.067	60-270	80-125	98-103	101

TABLE 2

Actual inside diameter of galvanized iron pipe, in inches

SIZE	PIPE A	PIPE B	PIPE C	PIPE D	AVERAGE
½	0.649	0.642	0.633	0.622	0.636
¾	0.845	0.839	0.834	0.830	0.837
1	1.062	1.064	1.050	1.053	1.057
1½	1.612	1.600	1.618	1.605	1.609
2	2.080	2.075	2.071	2.090	2.079

The ½-inch pipe shows the greatest difference. If the same difference had prevailed in the pipe upon which the loss of head tests were made and the actual diameters had been used in the computations, the effect would have been to reduce the values of *c* somewhat. In the case of the ½-inch this would have meant a reduction of 4 per cent. However, as it is usually quite difficult to measure the diameters accurately, values of *c* computed on the basis of the standard diameters would be of the greater value.

Figures 1 and 2 show the curves that were obtained for the various sizes of lead and galvanized iron pipe, respectively. They have been plotted to a logarithmic scale in order that they may appear as straight lines, and be therefore more easily comparable with one another. The points that have been indicated are the values for the different sections from 2 to 4 feet long, and indicate the variations in the different parts of the same length. For the lead pipe, curves have been added in which *c* has a value of 120 and 160; and similarly for the galvanized pipe, curves in which *c* has a value of 80 and 120.

TABLE 3

Values of c, coefficient of discharge, of corporation cocks

SIZE	TAIL PIECE, ANGLE	VELOCITY IN FEET PER SECOND	
		10	30
inches	*degrees*		
½	45	0.433	0.467
⅝	45	0.496	0.500
	90	0.367	0.388
¾	45	0.433	0.443
	90	0.380	0.408
1	45	0.445	0.445
	90	0.478	0.478
1½	45	0.577	0.590
	90	0.567	0.548
1½*	45	0.351	0.298
	90	0.300	0.322
2	45	0.459	0.467
	90	0.433	0.431
2*	45	0.306	0.326
	90	0.292	0.308

* Strainer.

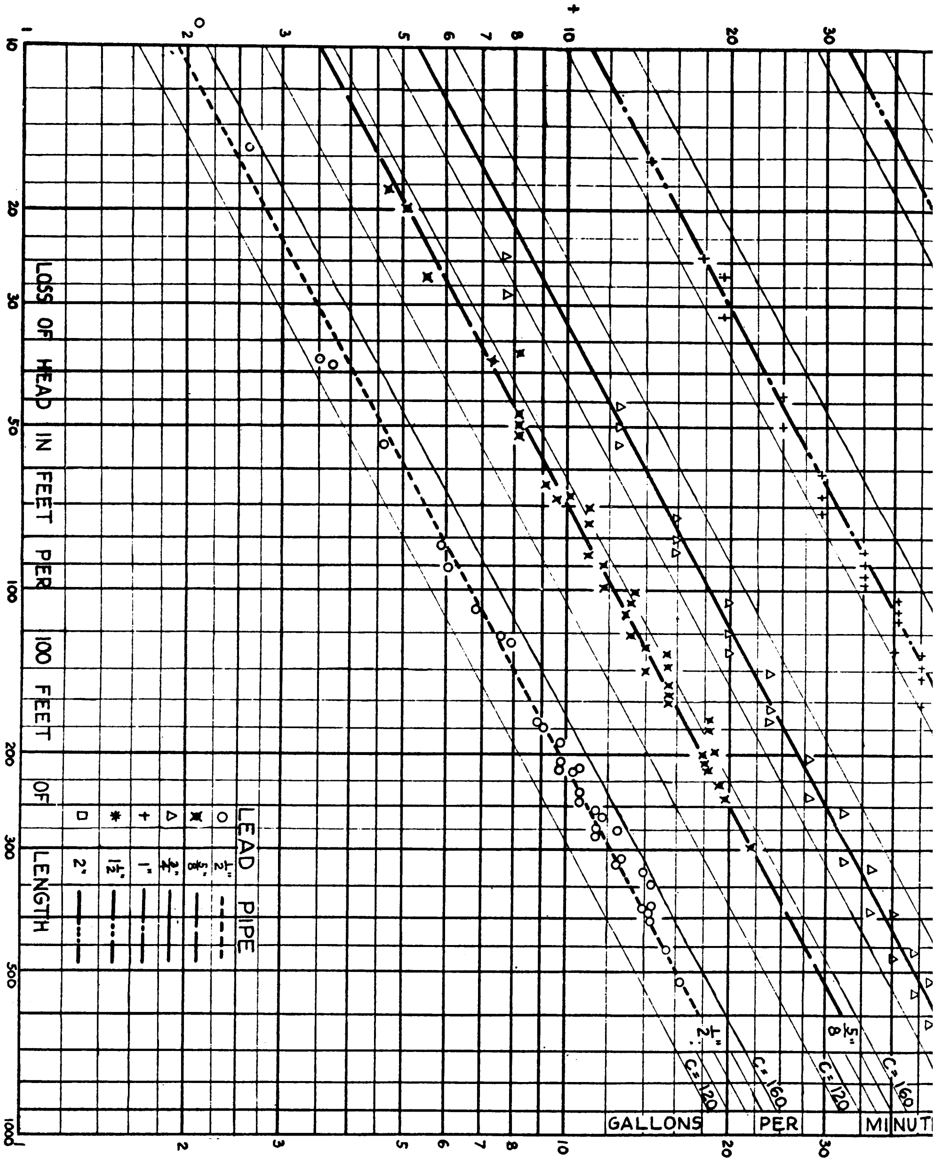
LOSS OF HEAD IN FEET PER 100 FEET OF LENGTH
GALLONS PER MINUT
LEAD PIPE
○ 1/2"
✖ 5/8"
▷ 3/4"
+ 1"
✱ 1 1/2"
□ 2"
1/2"
5/8"
C=120
C=160
C=120
C=160
10
20
30
50
100
200
300
500
1000
2
3
5
6
7
8
10
20
30

FIG. 1

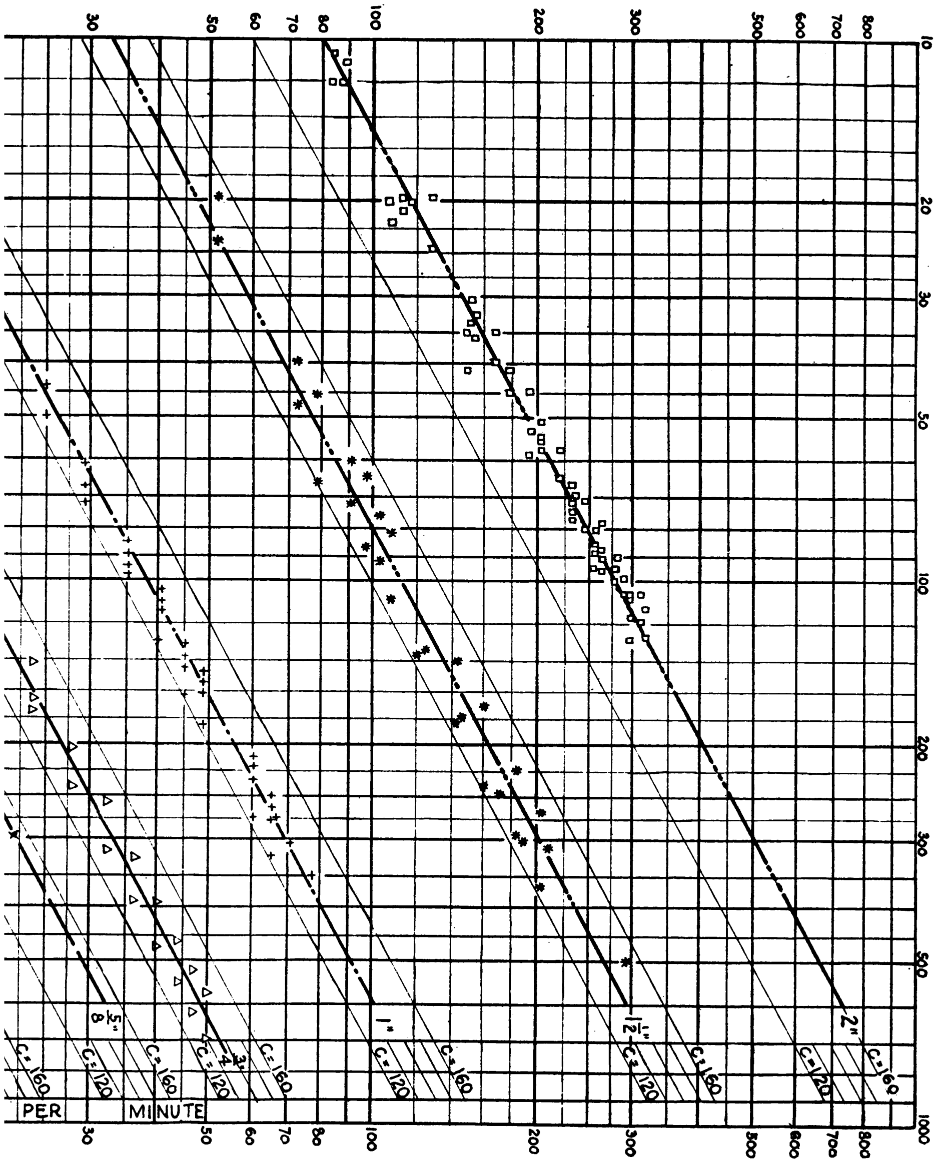
30
50
60
70
80
100
200
300
500
600
700
800
10
20
30
50
100
200
300
500
1000
5/8"
3/4"
1"
1 1/2"
2"
C=160
C=120
C=160
C=120
C=160
C=120
C=160
C=120
C=160
C=120
PER MINUTE

Fig. 1

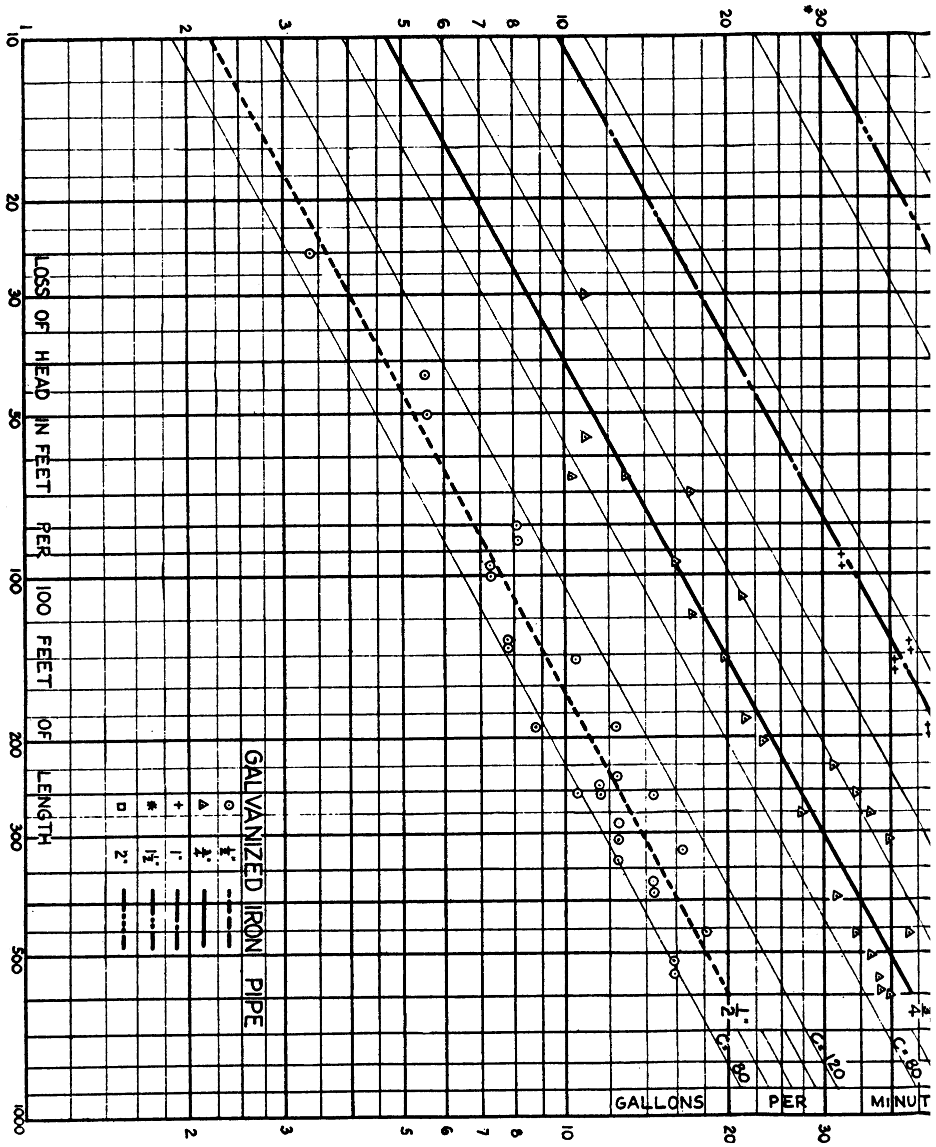
GALVANIZED IRON PIPE
⊙ ½"
△ ¾"
+ 1"
✱ 1½"
□ 2"
LOSS OF HEAD IN FEET PER 100 FEET OF LENGTH
GALLONS PER MINUT
10
20
30
50
100
200
300
500
1000
1
2
3
5
6
7
8
10
20
30
½"
C=80
C=120
C=80
¾"

Fig. 2

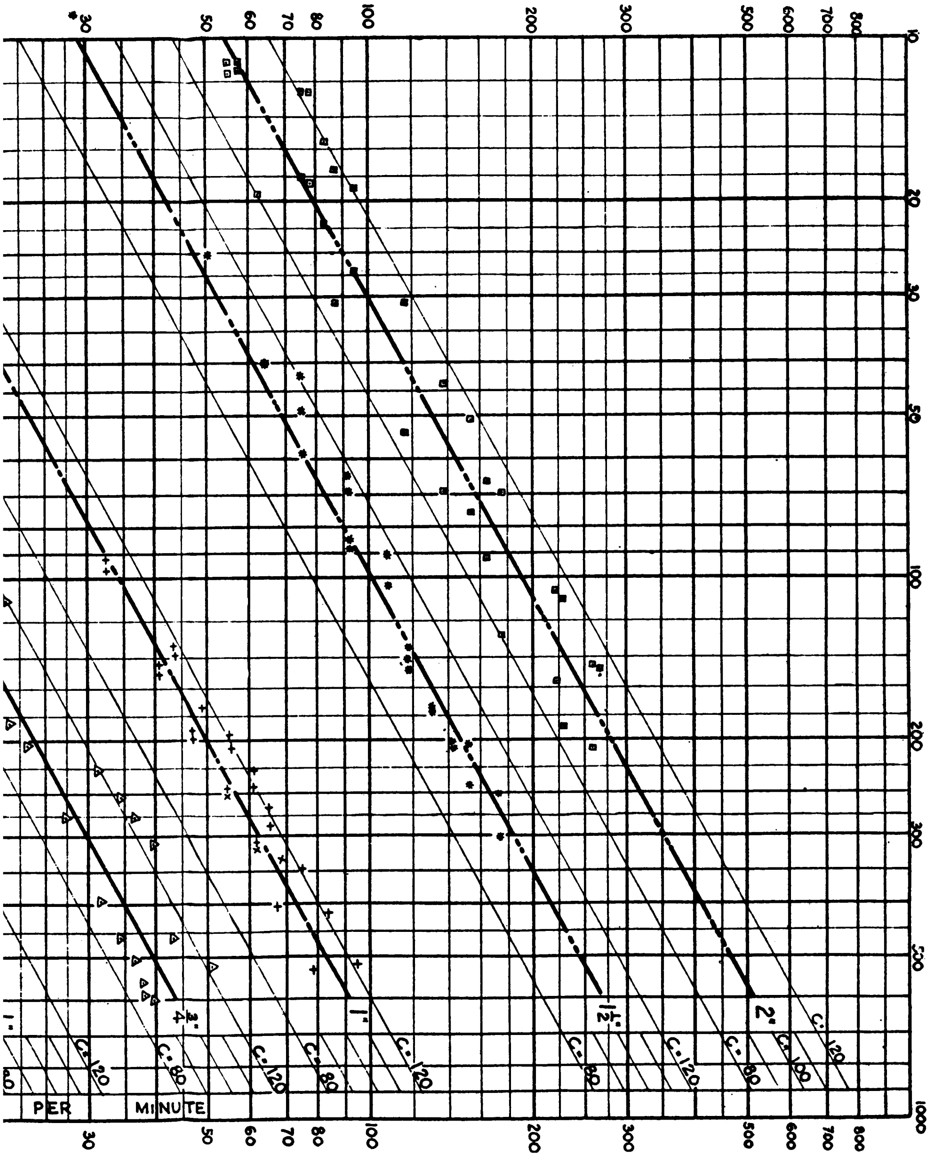
30
50
60
70
80
100
200
300
500
600
700
800
10
20
30
50
100
200
300
500
1000
3/4"
1"
1½"
2"
C=120
C=80
C=120
C=80
C=120
C=80
C=120
C=80
C=100
C=120
PER MINUTE

Fig. 2

Figure 3 shows some typical sections and table 7 the principal dimensions of the various sizes and styles of corporation cocks that were tested. Cocks with strainers or eel guards are no longer used by the department. They clogged up more quickly, and were more difficult to blow out than the cocks without the guards.

TABLE 4

Lengths of lead service pipe having same resistance to flow as corporation cocks

SIZE	TAIL PIECE, ANGLE	RANGE OF DISCHARGE	CORRESPONDING RANGE OF EQUIVALENT LENGTH OF LEAD PIPE
inches	*degrees*	*gallons per minute*	*feet*
$\frac{1}{2}$	45	3.5– 22.5	3.86– 4.70
$\frac{5}{8}$	45	6.0– 35.0	4.96– 5.94
	90	5.0– 35.0	6.24– 7.54
$\frac{3}{4}$	45	8.0– 50.0	5.67– 7.17
	90	7.0– 50.0	6.65– 7.72
1	45	14.0–100.0	7.47– 9.91
	90	16.0–100.0	7.00– 9.23
$1\frac{1}{2}$	45	70.0–250.0	10.00–12.38
	90	70.0–250.0	10.22–13.52
$1\frac{1}{2}$*	45	30.0–160.0	14.10–23.45
	90	25.0–180.0	18.20–21.45
2	45	60.0–400.0	22.60–28.50
	90	60.0–400.0	22.95–31.10
2*	45	80.0–350.0	34.00–40.00
	90	80.0–300.0	36.00–40.75

* Strainer.

Figure 4 shows the curves obtained for the corporation cocks. They have also been plotted to a logarithmic scale. The losses shown include the velocity head, entrance head, and the frictional loss in the cock. The velocity head curves for the different sizes have also been plotted.

It will be noted that with one exception, the losses through the cocks with 90 degree tail pieces are larger than those with 45 degree tail pieces, the difference being greater for the smaller sizes. The addition of a strainer or eel guard practically doubles the loss.

The relation between the loss in the corporation cock and the velocity head may be expressed by the formula $C = H/P$, in which

TABLE 5

Pressure in street mains in pounds per square inch required to give the tabulated discharge through a corporation cock and 30 feet of lead service pipe

FLOW	DIAMETER OF LEAD PIPE, WITH SERVICE COCK SIZES BELOW																	
	2 inch							1½ inch					1 inch			¾ inch		⅝ inch
	2 inch	2 inch*	1½ inch	1½ inch*	1 inch	¾ inch	⅝ inch	1½ inch	1½ inch*	1 inch	¾ inch	⅝ inch	1 inch	¾ inch	⅝ inch	¾ inch	⅝ inch	⅝ inch
gallons per minute		*		*					*									
5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	3
10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	6	10
15	..	..	..	..	..	..	..	..	..	..	..	..	3	4	5	11	12	23
20	..	..	..	..	..	..	5	..	..	..	..	5	5	6	9	18	21	38
25	..	..	..	..	..	3	7	..	..	..	4	8	8	10	14	28	32	54
30	..	..	..	..	..	5	11	..	..	2	5	12	11	14	20	39	46	
40	..	..	..	..	3	8	19	2	3	4	10	21	18	24	35	69	80	
50	..	..	..	..	4	13	30	4	5	7	15	32	28	37	54			
60	..	..	..	3	6	18	43	5	7	9	22	47	39	51	76			
70	..	..	..	4	8	25	63	7	9	13	30	68	52	69				
80	..	..	..	5	10	33	..	9	11	17	40		68					
90	..	3	3	6	13	42	..	12	14	21	52							
100	3	4	4	7	16	51	..	14	17	26								
125	5	6	7	12	25	77	..	22	27	40								
150	8	9	10	17	36	..	..	30	38	57								
175	10	12	13	23	49	..	..	41	51	77								
200	13	16	17	29	62	..	..	52	65									
225	17	20	21	37	..	..	..	65										
250	20	24	25	45														
275	24	29	30	55														
300	29	35	36	64														

* With strainer.

H is the velocity head, and P the total loss as measured by the U-tube minus the loss through the 1 foot of lead pipe. The value of C is not a constant, being in general higher for the larger values of H. The loss P also represents the pressure required to produce the velocity head H, hence C is equal to the coefficient of discharge. Table 3 gives the values of C as computed from the curves on figure 4.

The relation between the losses in the corporation cocks and the losses in pipe can be shown by computing the length of lead pipe of a size corresponding to the size of the cock, in which the loss would be the same. This equivalent length is not a constant, being greater for the higher rates of flow and for the larger cocks. Table 4 gives the range in the values of this length for the various sizes and rates of flow indicated.

The values at other rates than those indicated may be obtained by direct proportion without material error.

TABLE 6

Loss of head in pounds per square inch in 10 feet of lead pipe; velocity head not included

GALLONS PER MINUTE	⅝ inch	¾ inch	1 inch	1½ inch	2 inch
5	1				
10	2	2			
15	6	3			
20	10	5	1		
25	14	8	2		
30	....	11	3		
40	....	18	5		
50	....	....	7		
60	....	....	10	1	
70	....	....	13	2	
80	....	....	17	2	
90	....	....	....	3	
100	....	....	....	3	
125	....	....	....	5	
150	....	....	....	7	1
175	....	....	....	10	2
200	....	....	....	12	2
225	....	....	....	15	3
250	....	....	....	....	3
275	....	....	....	....	4
300	....	....	....	....	5

Tables 5 and 6 were prepared from the results of these tests and have been found to be quite useful. Table 5 gives the pressures required on the street main in pounds per square inch to discharge through the various combinations of corporation cocks and service pipes, the rates of flow indicated. The figures are also equivalent to the difference in pressure between the street main and the end of the service pipe when discharging into the house plumbing under

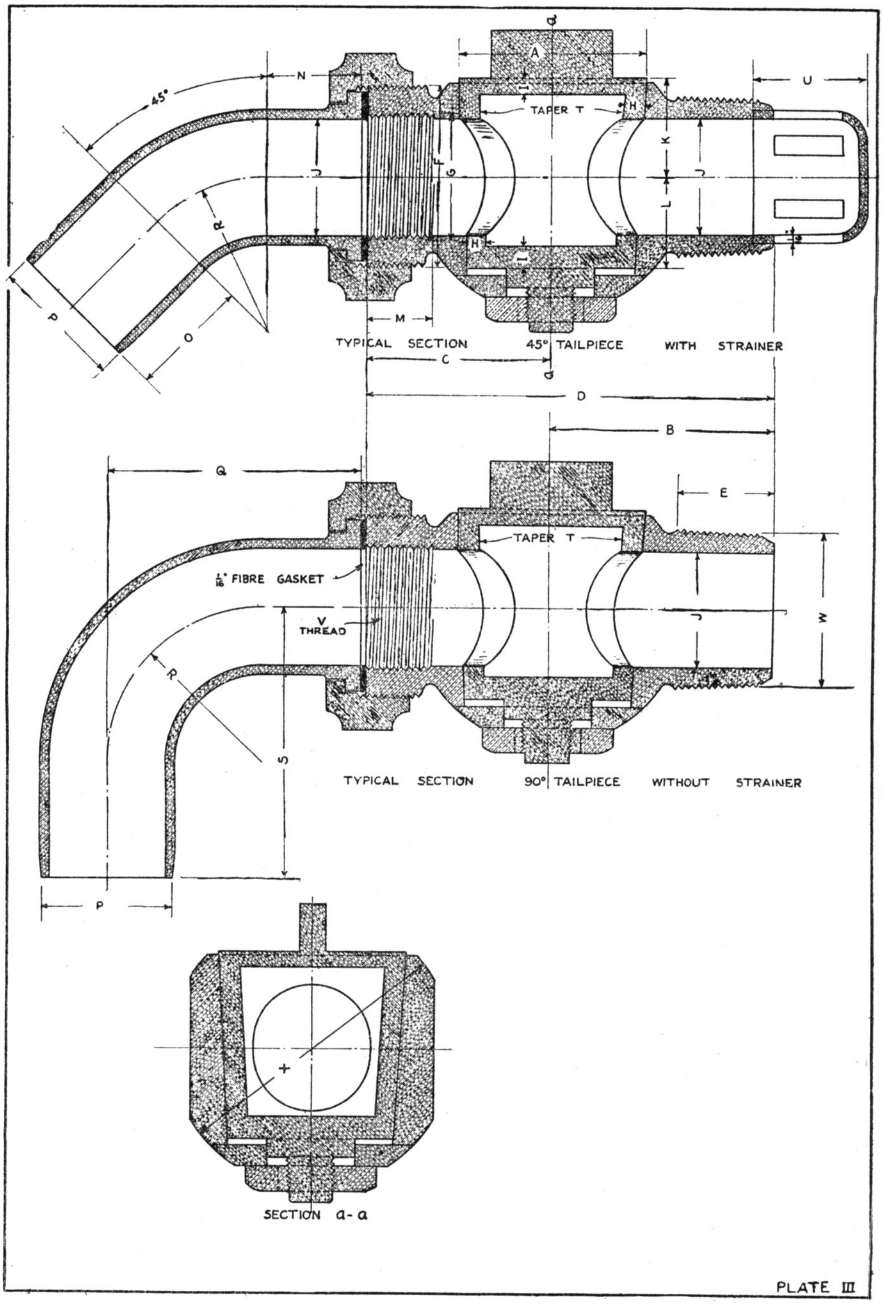
a
A
N
45°
TAPER T
H
I
U
J
F
G
K
L
R
P
O
M
1/16"
TYPICAL SECTION 45° TAILPIECE WITH STRAINER
C
D
B
Q
E
TAPER T
1/16" FIBRE GASKET
V THREAD
J
W
R
S
P
TYPICAL SECTION 90° TAILPIECE WITHOUT STRAINER
SECTION a-a

PLATE III

FIG. 3. SECTIONS OF CORPORATION COCKS TESTED

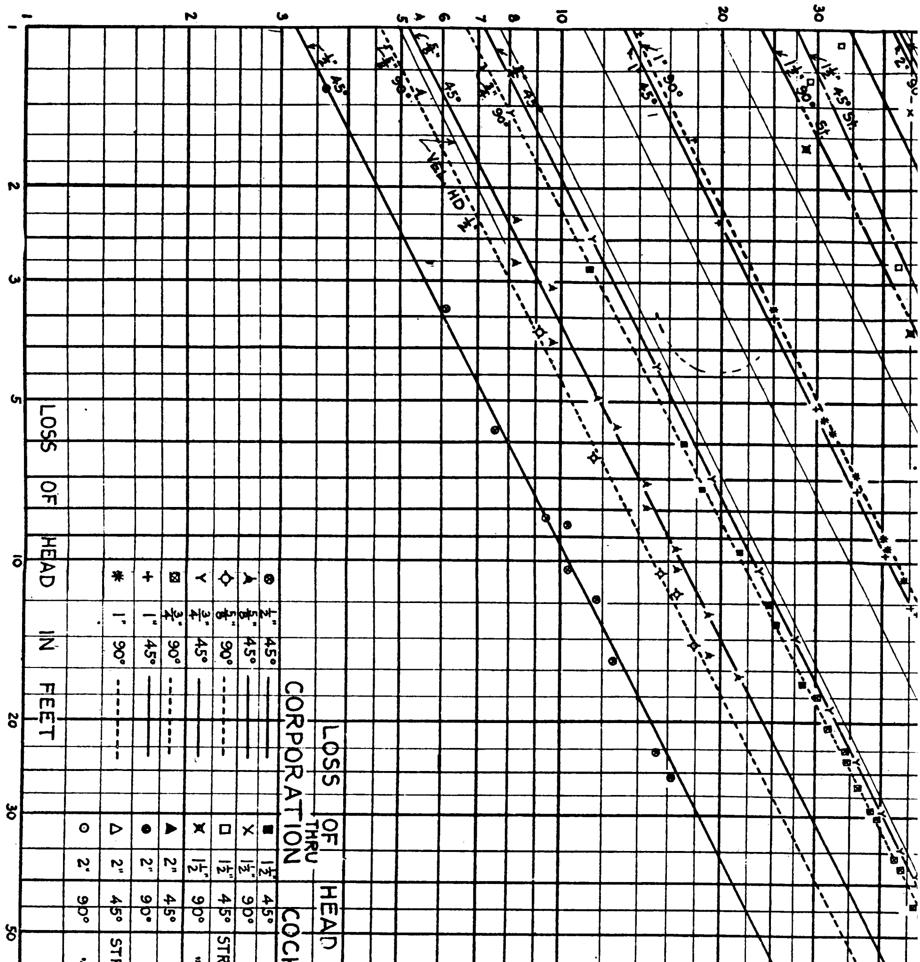
LOSS OF HEAD THRU CORPORATION COCKS
LOSS OF HEAD IN FEET
GALLONS PER
1
2
3
5
10
20
30
50
100
1
2
3
5
6
7
8
10
20
30
1/2" 45°
5/8" 45°
5/8" 90°
3/4" 45°
3/4" 90°
1" 45°
1" 90°
1 1/2" 45°
1 1/2" 90°
1 1/2" 45° STRAINER
1 1/2" 90° " "
2" 45°
2" 90°
2" 45° STRAINER
2" 90° " "
VEL. HD 1/2"
VEL. HD

FIG. 4

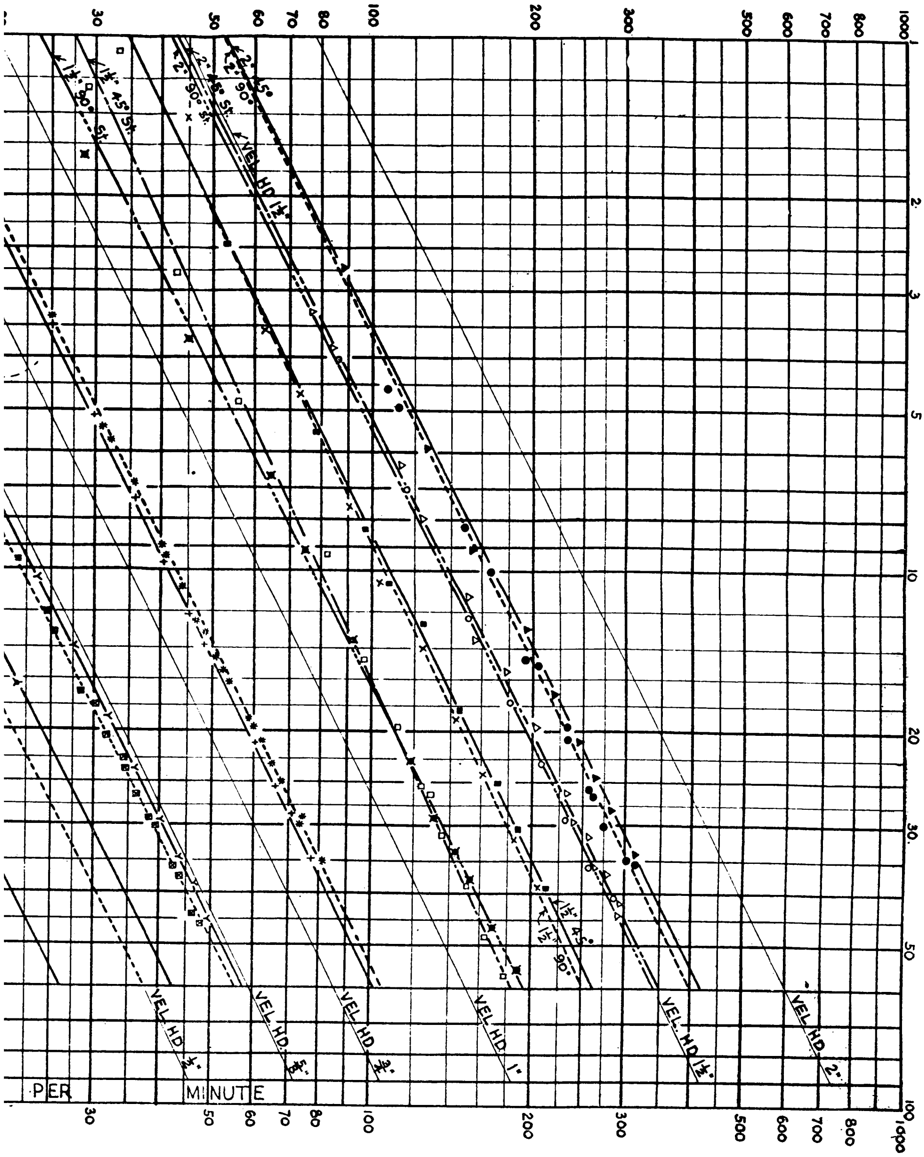
30
50
60
70
80
100
200
300
500
600
700
800
1000
1
2
3
5
10
20
30
50
100
PER MINUTE
1½" 90° St.
1½" 45° St.
2" 90° St.
2" 45° St.
2" 45°
2" 90°
VEL. HD. 1½"
1½" 45°
1½" 90°
VEL. HD. ½"
VEL. HD. ⅝"
VEL. HD. ¾"
VEL. HD. 1"
VEL. HD. 1½"
VEL. HD. 2"

FIG. 4

pressure. The length of the service pipe has been taken as 30 feet. Table 6 gives the loss through 10 feet of lead pipe. From these two tables the pressure required for any length of lead service can be readily computed.

TABLE 7

Dimensions of various sizes of corporation cocks illustrated in figure 3

	$\frac{1}{2}$ INCH	$\frac{5}{8}$ INCH	$\frac{3}{4}$ INCH	1 INCH	$1\frac{1}{2}$ INCH	2 INCH
A	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{21}{64}$	$1\frac{5}{8}$	$2\frac{29}{64}$	$3\frac{3}{8}$
B	$1\frac{7}{8}$	$1\frac{7}{8}$	2	$2\frac{3}{32}$	$2\frac{7}{8}$	$3\frac{13}{16}$
C	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{21}{32}$	$2\frac{7}{16}$	$3\frac{1}{4}$
D	$3\frac{3}{8}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{5}{16}$	$7\frac{1}{16}$
E	1	1	1	$\frac{15}{16}$	$1\frac{1}{4}$	$1\frac{9}{16}$
F	0.944	$1\frac{9}{32}$	$1\frac{9}{32}$	1.605	2.351	2.853
G	0.632	0.753	0.878	1.112	$1\frac{11}{16}$	$2\frac{3}{16}$
H	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
I	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
J	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2
K	$\frac{23}{32}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{3}{4}$
L	$\frac{17}{32}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{13}{16}$	$1\frac{3}{16}$	$1\frac{9}{16}$
M	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$1\frac{3}{8}$
N	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
O	$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$
P	$\frac{21}{32}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{3}{16}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Q	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$
R	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	2
S	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$
U					$1\frac{3}{16}$	$1\frac{1}{4}$
V	12	12	12	12	8	8
W	0.822	1.053	1.145	1.361	2.024	$2\frac{9}{16}$
X	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{11}{16}$	$4\frac{7}{8}$
T (TAPER)	$1\frac{1}{4}$″-1′0″	$1\frac{1}{4}$″-1′0″	$1\frac{1}{4}$″-1′0″	$1\frac{1}{4}$″-1′0″	1″-1′0″	1″-1′0″
Strainer { Number of openings					6	10
Strainer { Size of openings					$\frac{7}{8}$″x$\frac{5}{16}$″	$1\frac{1}{8}$x$\frac{5}{16}$″